aresys
Advancing remote sensing

S-1 MPC

The in-orbit performance of the Sentinel-1A C-SAR Instrument

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AUTHOR:	ARESYS S1A MPC team

Outline

1. **Introduction**
   - ESL INS within the S-1 MPC

2. **S-1A Instrument long-term performance monitoring**
   - Internal calibration:
     - PG – impact of temperature
     - SAR Antenna monitoring
   - Doppler Centroid
   - Burst synchronization
   - FDBAQ

ESL INS within the Sentinel-1 MPC

- Expert Support Laboratory – SAR Instrument

- Long term monitoring of key instrument performance parameters

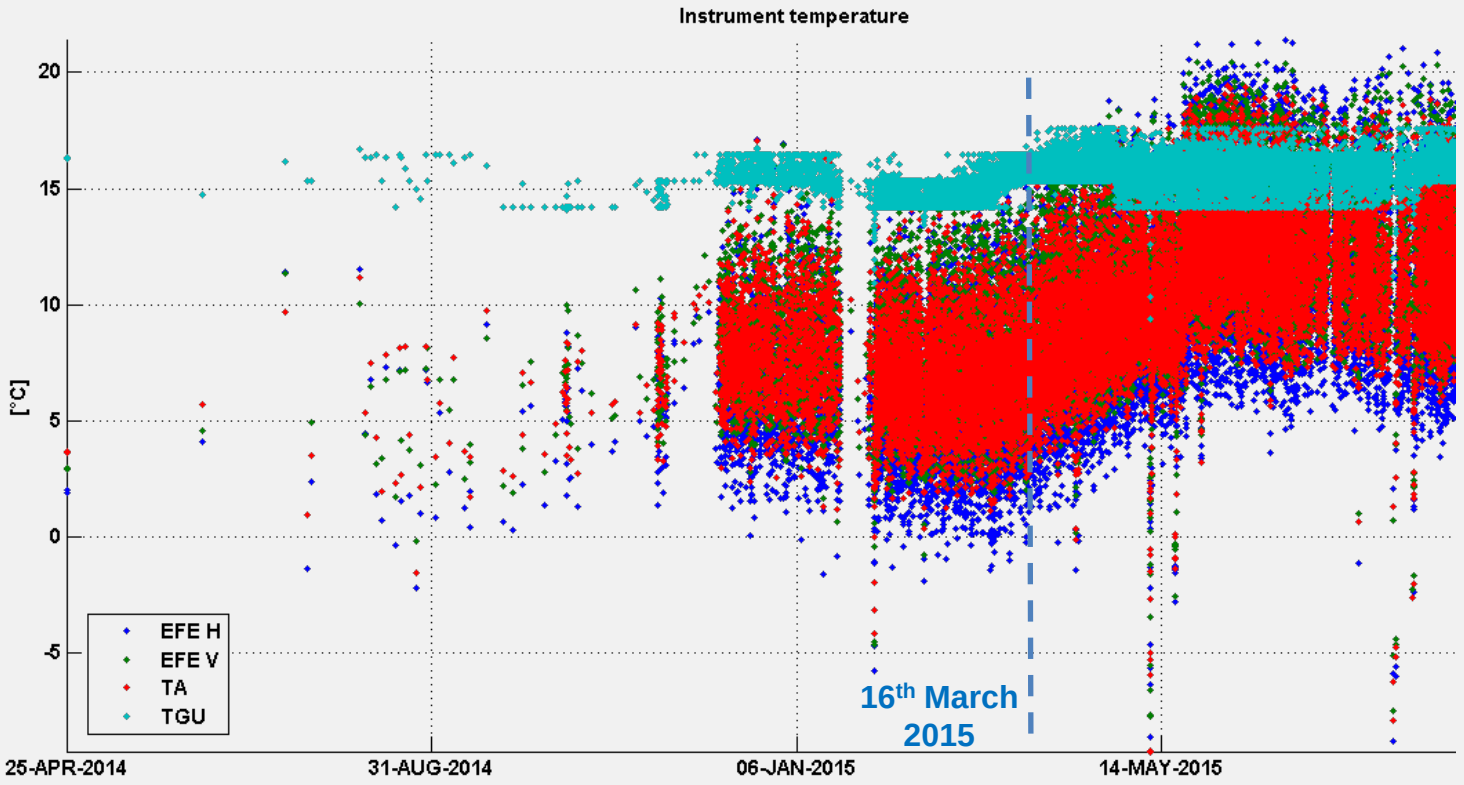
- Investigation of anomalies:
  - Detailed analyses of raw data, Internal cal signals
  - Impact on data quality

- Support to the maintenance of the instrument configuration (RADAR DATA BASE)

- Support to the maintenance of the L1 processing configuration

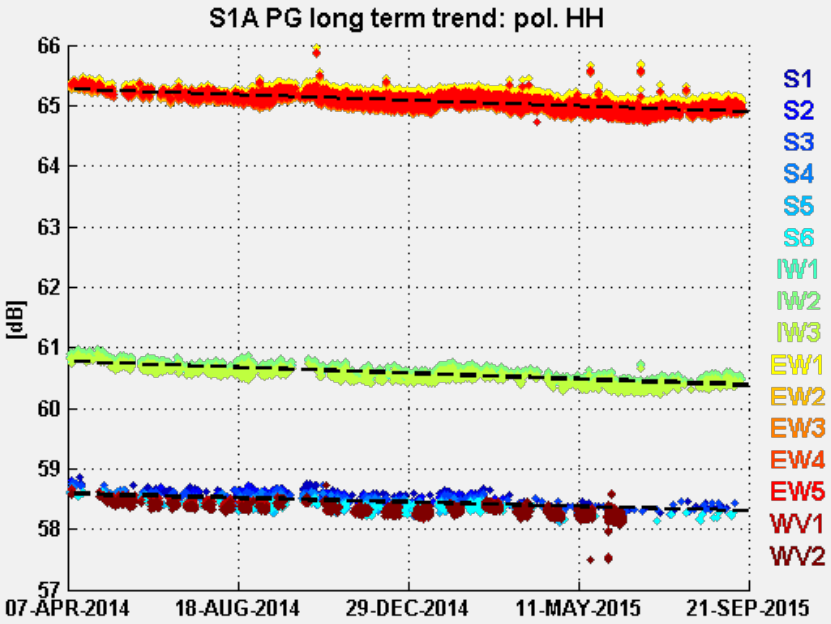
Internal Calibration monitoring

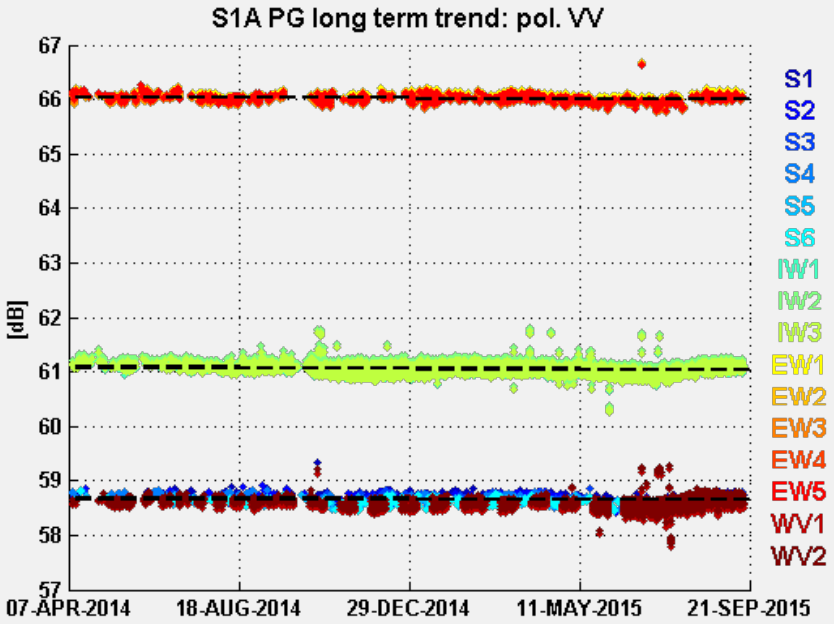
Temperature evolution



- Temperature increase since March 2015, related mainly to the increased instrument operation

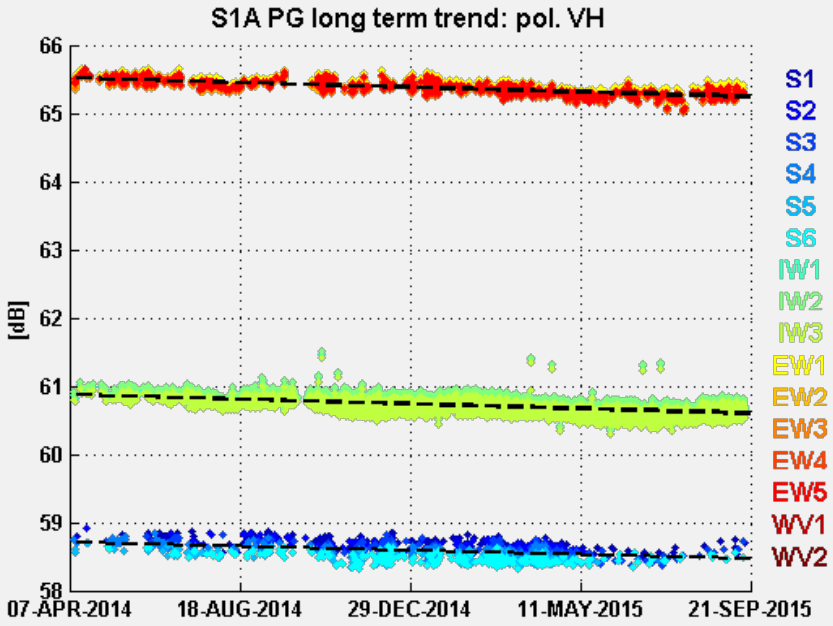
PG gain trend: co-pol

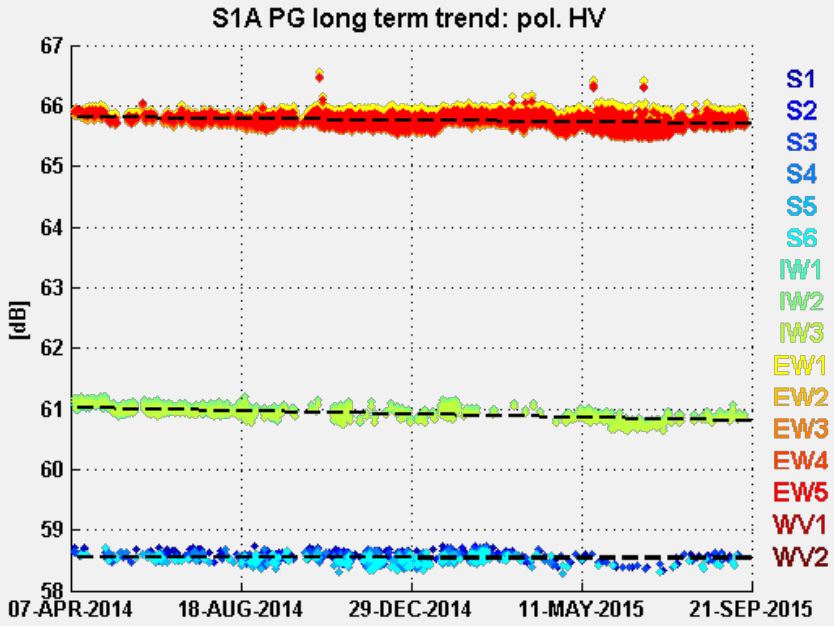




	HH	VV
SM	-0.20 dB/year	-0.01 dB/year
IW	-0.26 dB/year	-0.04 dB/year
EW	-0.25 dB/year	-0.02 dB/year

PG gain trend: cross-pol





	VH	HV
SM	-0.16 dB/year	-0.01 dB/year
IW	-0.19 dB/year	-0.09 dB/year
EW	-0.18 dB/year	-0.07 dB/year

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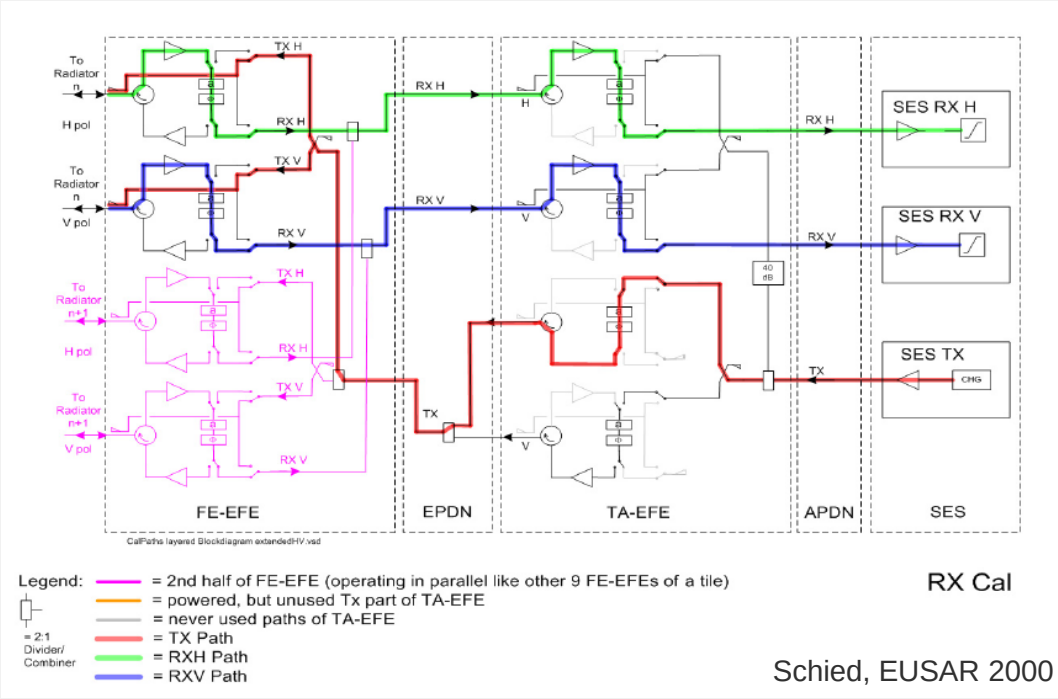
PG gain drift investigation

- PG drift of approx 0.2dB/year for rx-H polarization
- Investigation of the single elements' drift has been carried out

$$PG = \frac{TX \cdot RX \cdot TA}{EPDN \cdot APDN}$$



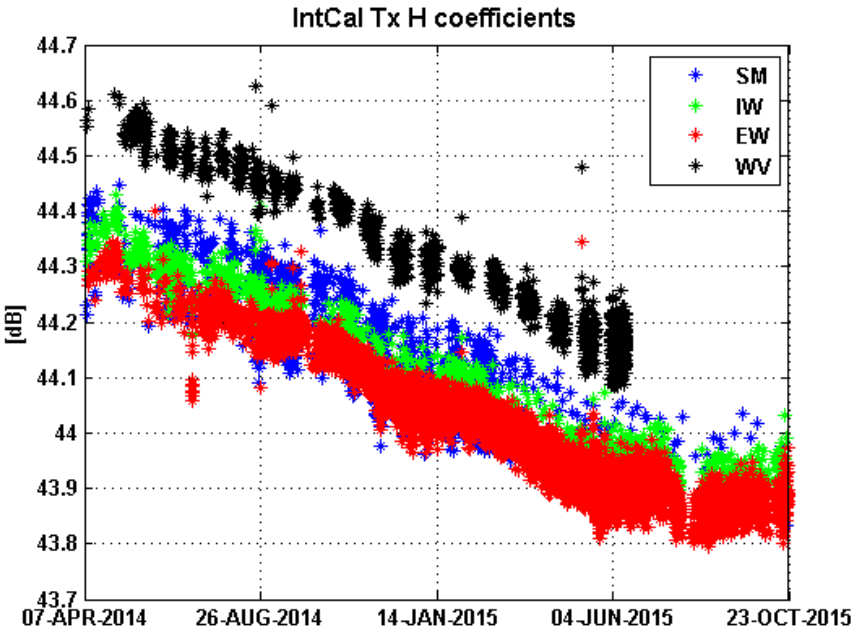
Schied, EUSAR 2000

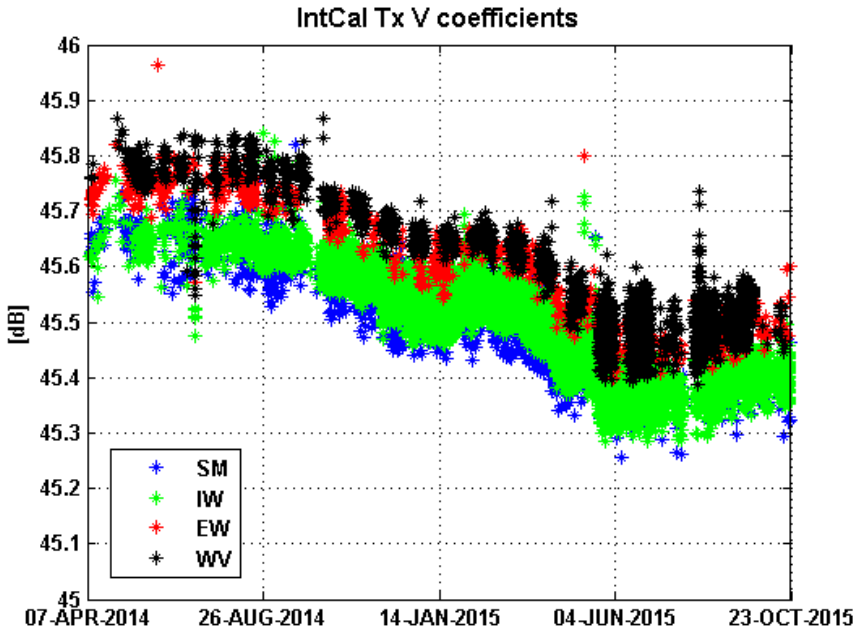
Considering coefficients trends in [dB/year] the following relationship applies:

$$PG_{TREND} = TX_{TREND} + \left(RX_{TREND} - EPDN_{TREND}\right) + \left(TA_{TREND} - APDN_{TREND}\right)$$

TX_{CHAIN} RX_{CHAIN} TA_{CHAIN}

Tx chain from IntCal

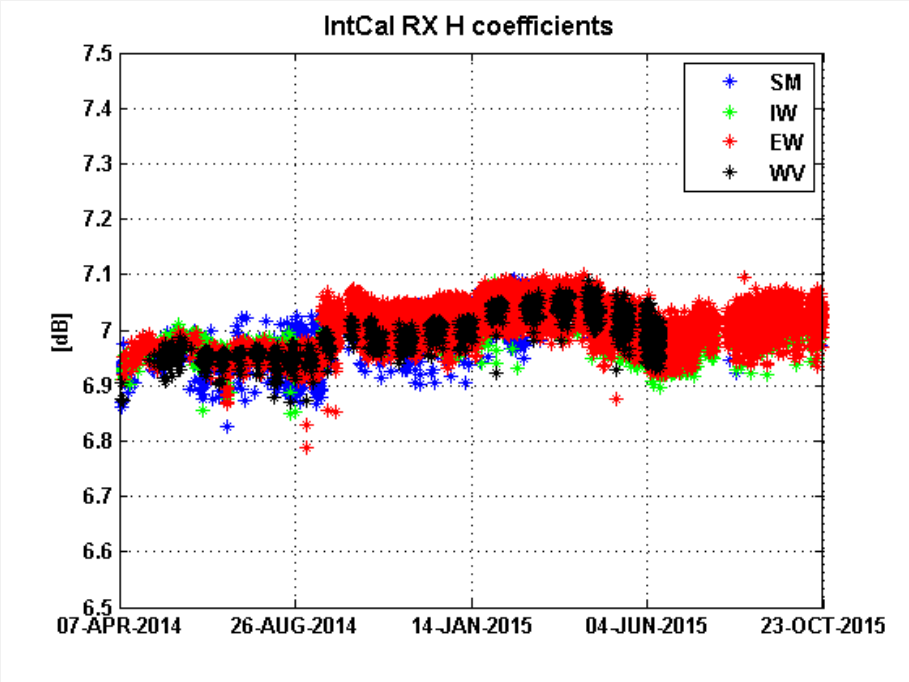


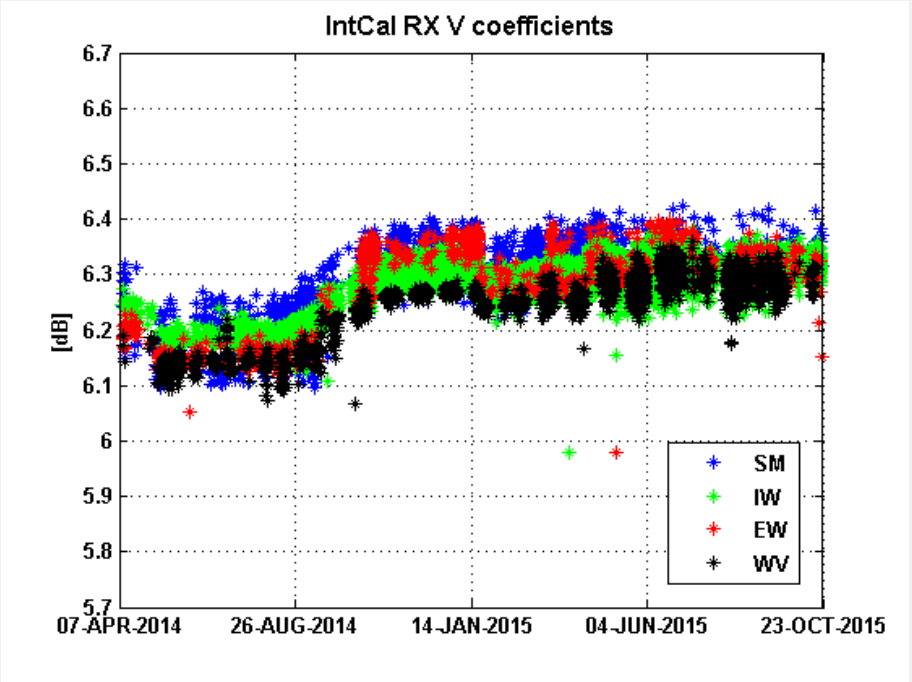


Trends calculated from 7th April 2014 to 31st May 2015

Mode	Tx H trend	Tx V trend
SM	-0.36 dB/year	-0.22 dB/year
IW	-0.35 dB/year	-0.25 dB/year
EW	-0.38 dB/year	-0.21 dB/year
WV	-0.38 dB/year	-0.29 dB/year

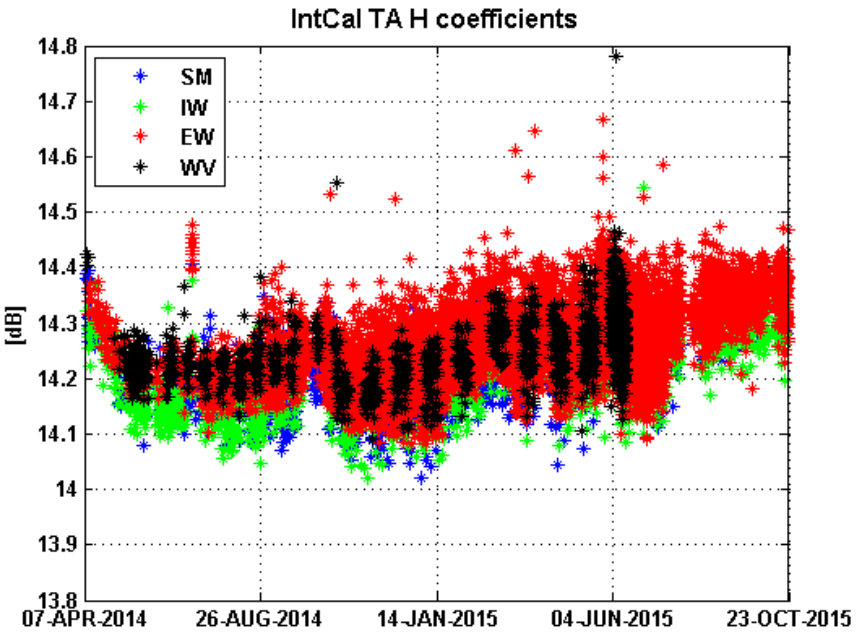
Rx chain from IntCal

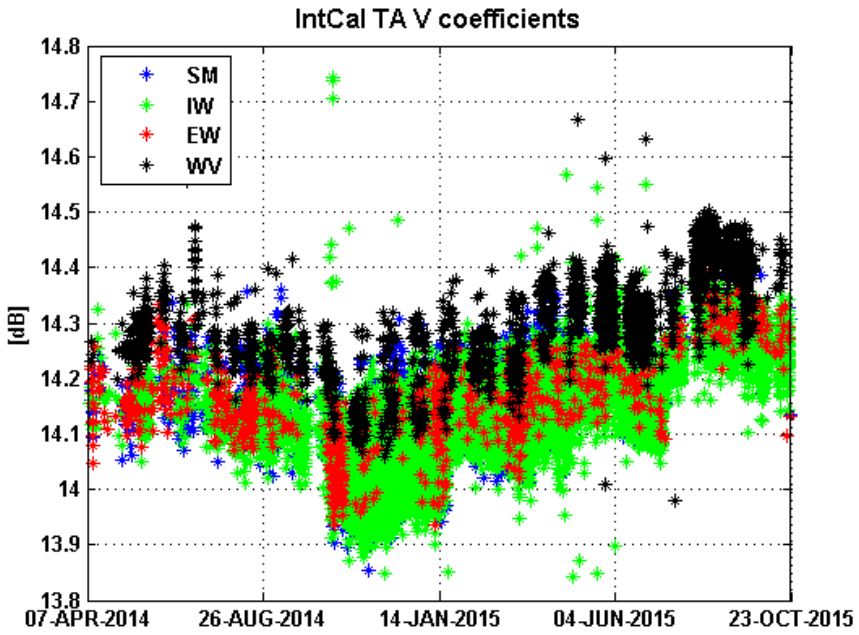




- RX H and V show a common stable trend, with a jump related to instr. Rx gain change occurred in September 2014

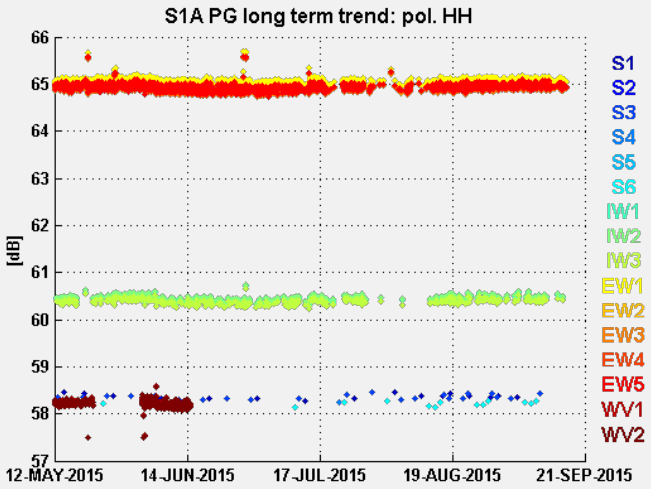
TA chain from IntCal

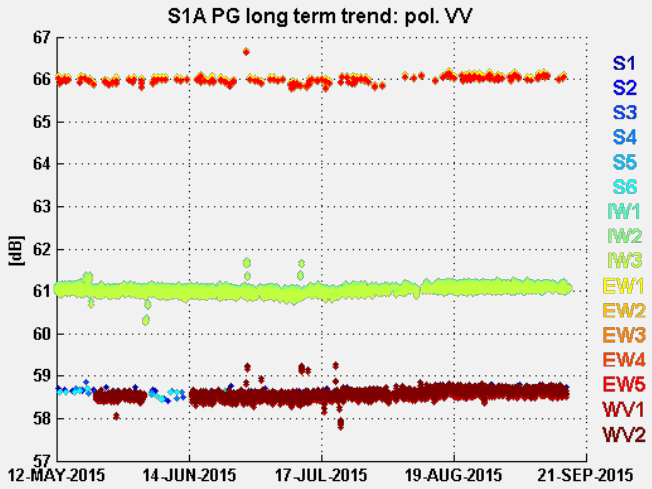


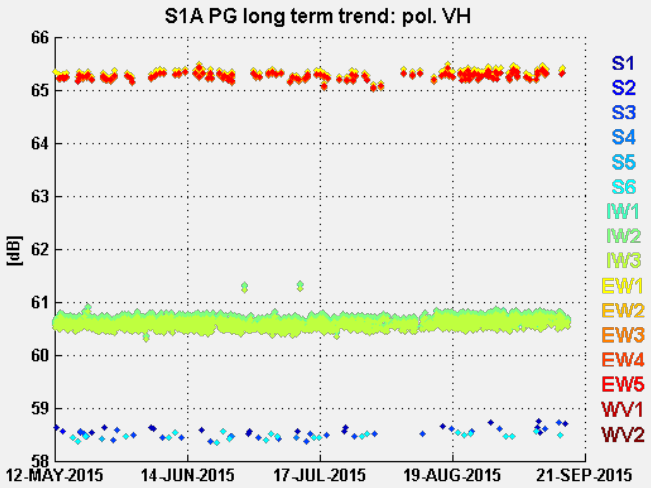


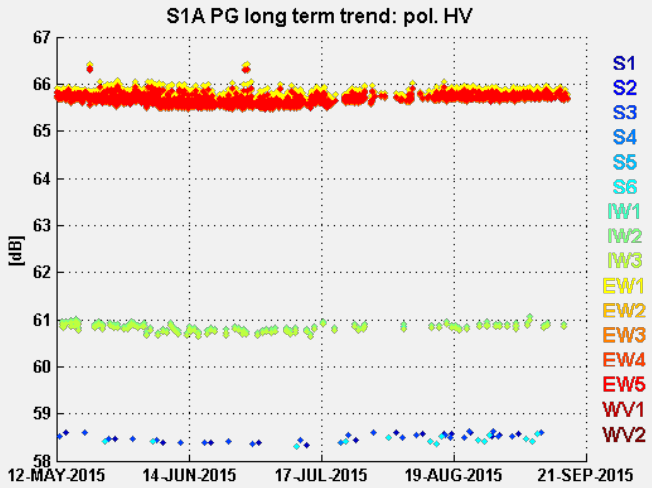
- TA V-pol shows a significant positive trend, compensating the TX negative trend

PG trend last 4 months





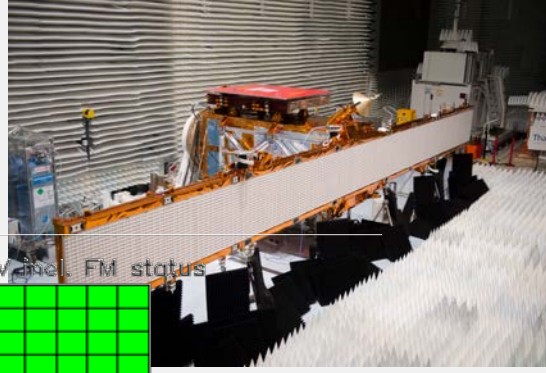




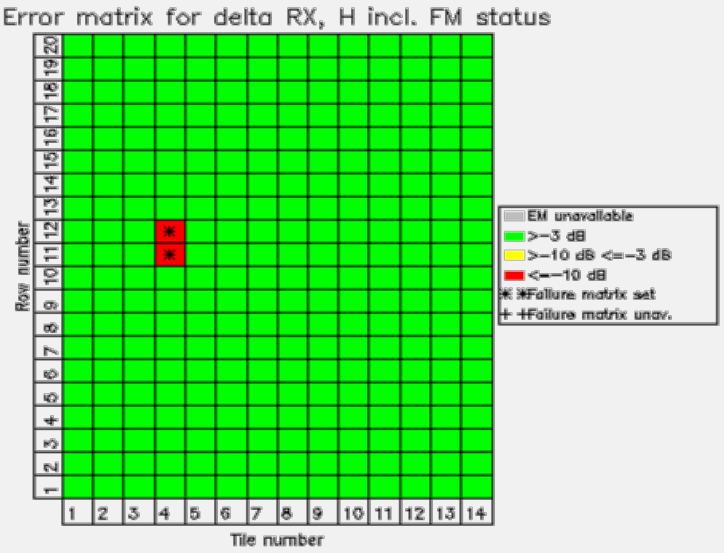
Internal calibration - summary

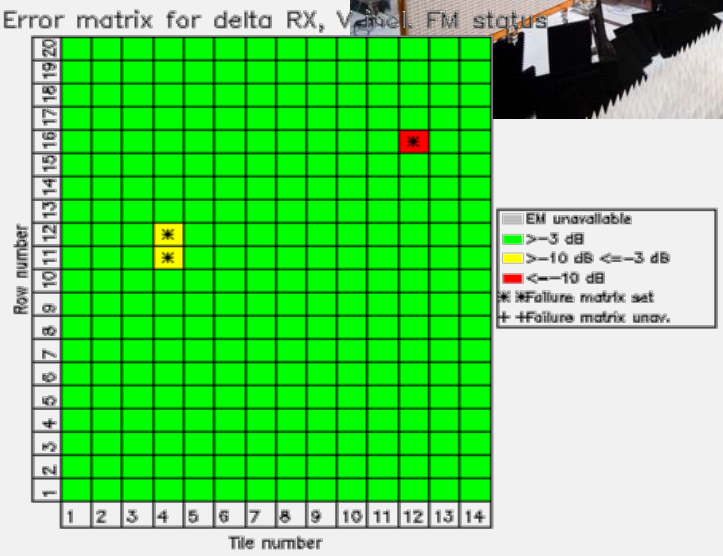
- PG drift of approx 0.2dB/year for rx-H polarization up to March 2015
- No drift for the rx-V polarization
- Investigation on the «source» of the drift indicates that:
  - The TX chain shows a negative trend
  - The RX chain shows a stable trend (except for a jump related to the instrument gain reconfiguration)
  - The TA V shows a positive trend (especially for V-pol), «compensating» the negative TX trend
- The increased instrument utilization since March 2015 (also seen from the increased temeperature analysis) mitigates the drifts.
- The drift is captured by the internal calibration: no impact on data quality

SAR Antenna TRMs status

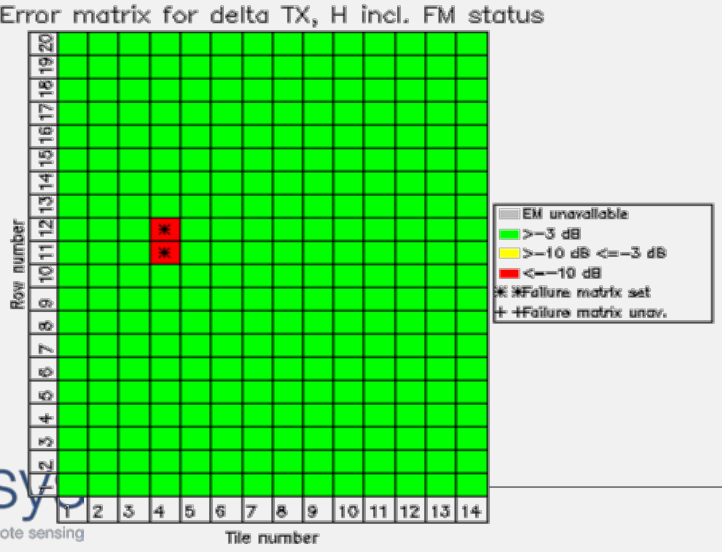


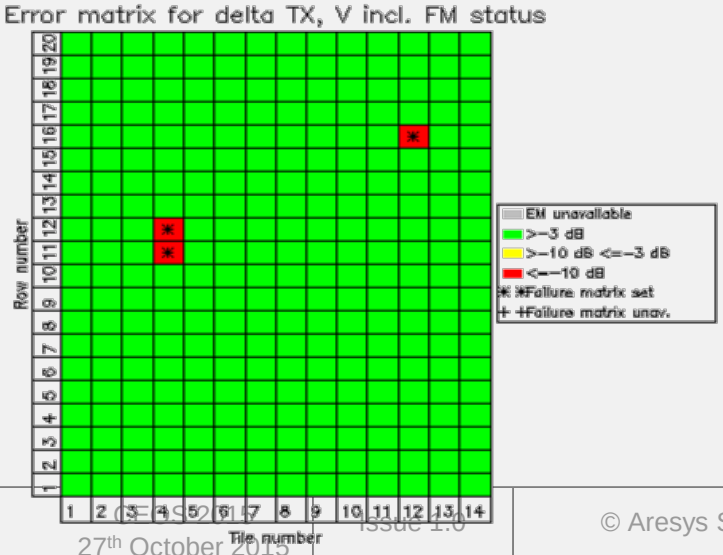
RX





TX

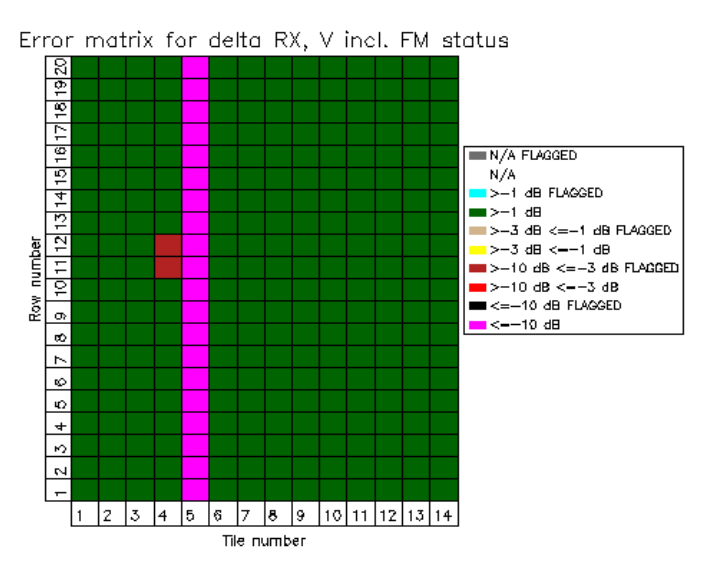




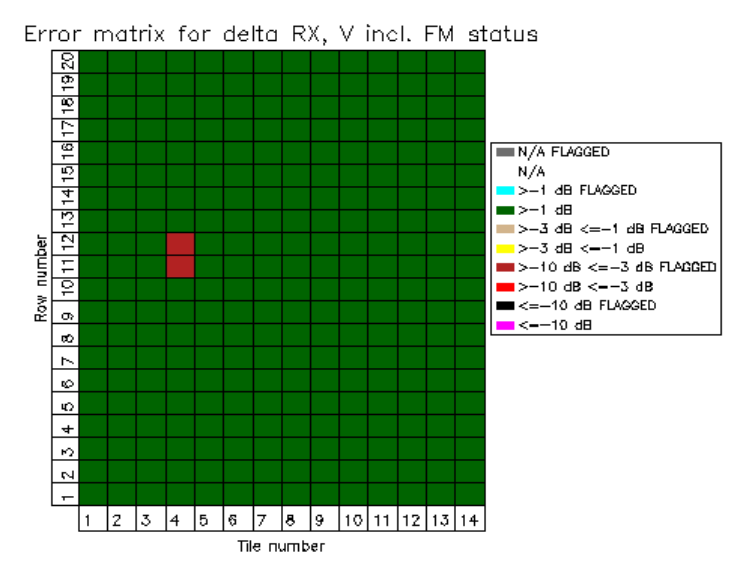
Antenna TRMs status evolution:

Date	TILE	ROWs	TX/RX – H/V	Description
5-May-2014	4	11,12	TX H, TX V, RX V	Failure
9-Jun-2014	4	12	RX H	Failure
29-Apr-2015	4	11	RX H	Failure
16-18 Apr 2015 20-28 Apr 2015 01-04 May 2015	12	16	TX V, RX V	Intermittent failure
18-May-2015, 22:33:36 UT	12	16	TX V, RX V	Failure
18 Oct 2014 to 20 Jan 2015 18-20 Mar 2015 26-28 Mar 2015 18-24 Apr 2015 25-30 Apr 2015 05-06 May 2015 26-27 May 2015 06-14 July 2015 17-21 July 2015	5	1-20	RX H, RX V	Intermittent failure
22 July 2015	5	1-20	RX H, RX V	Switch to redundancy (RDB#5)

Closer look to Tile#5



20150118

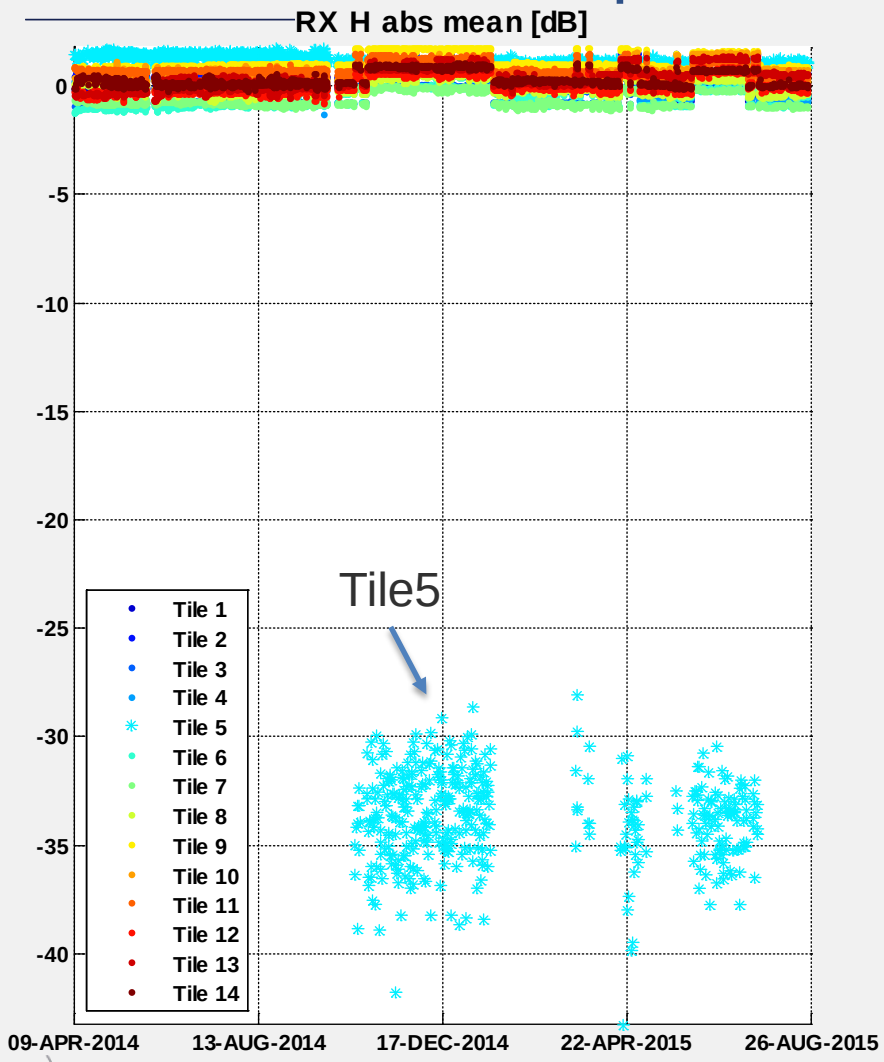


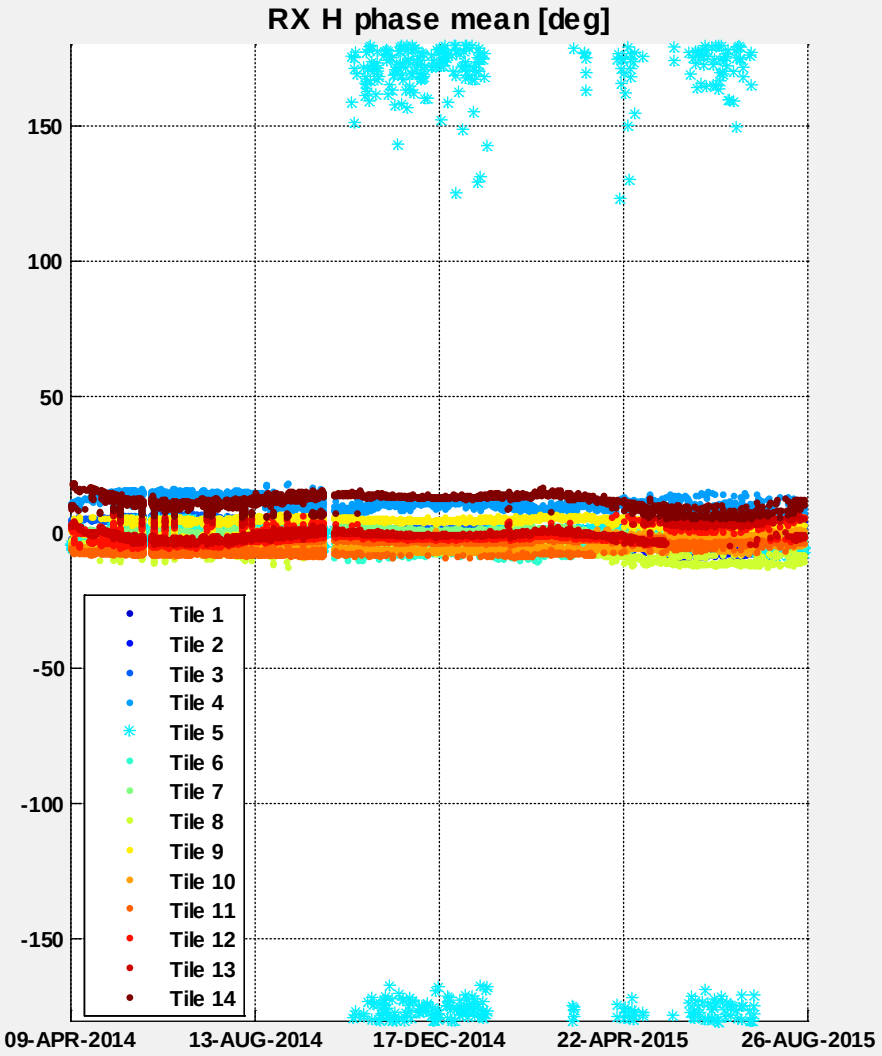
20150119

- Intermittent failure of complete tile (RX only, both polarizations)

Antenna coefficients from RFC (average over rows)

Since launch – H pol





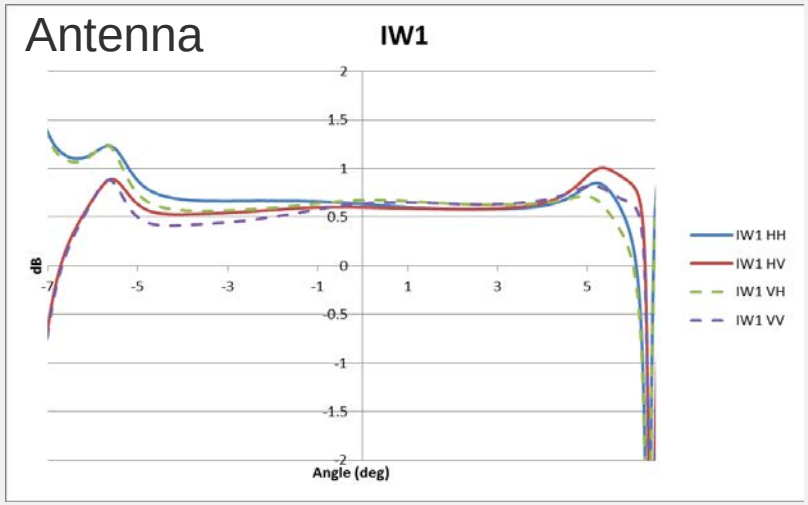
Investigation of the impact on data quality

- Impact on antenna directivity ➔ reduction close to 13/14 (0.7 dB)

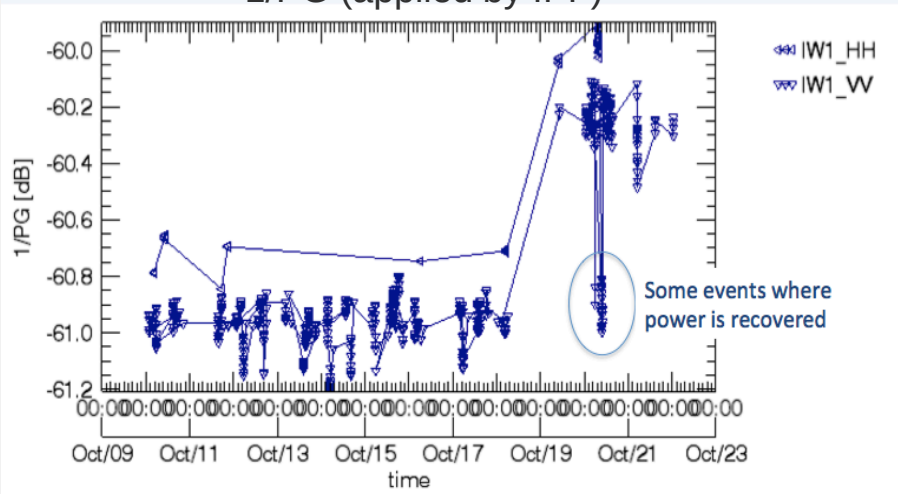
- The effect impacts the PG, which shows a consistent power variation

➔ The radiometric accuracy of the data is not impacted

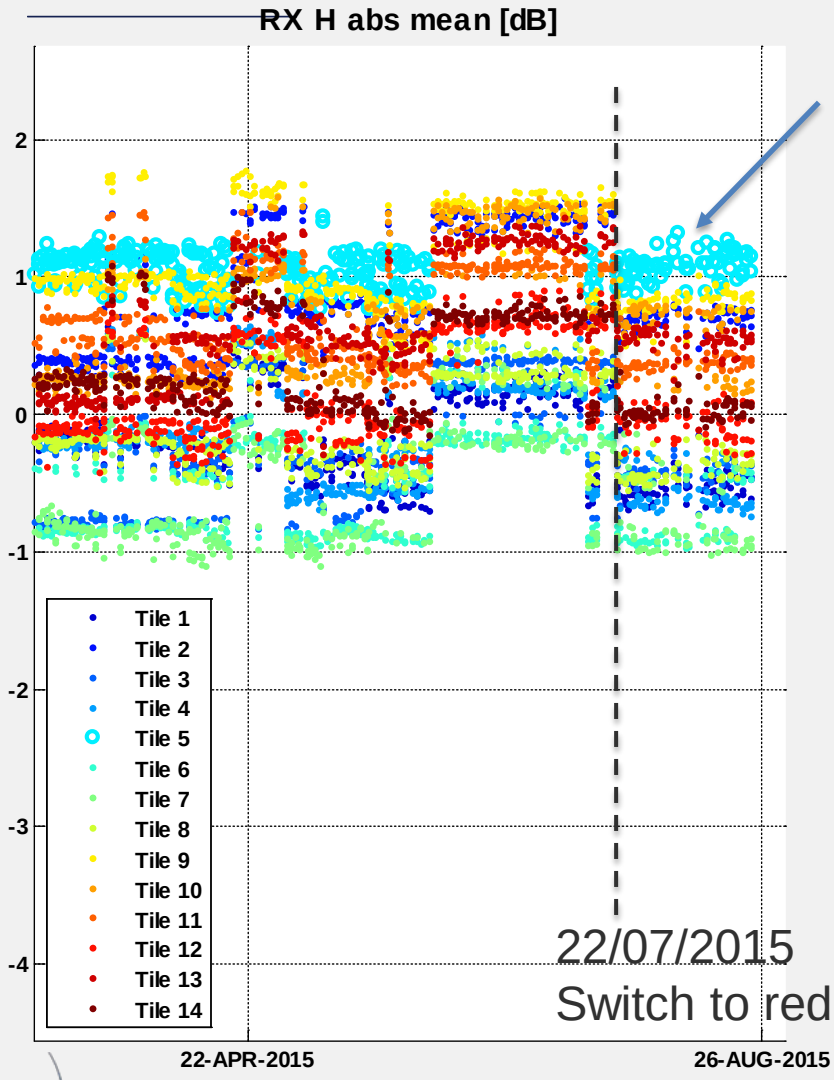
- The NESZ is increased by the same amount

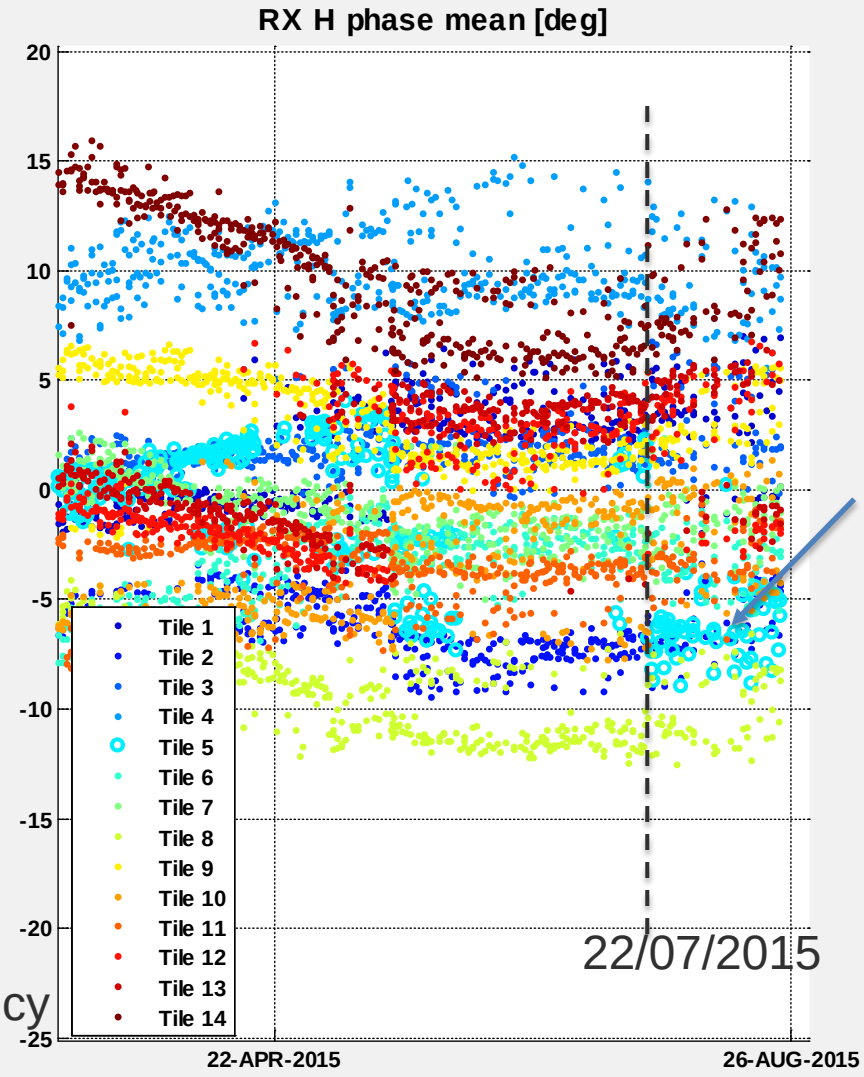


1/PG (applied by IPF)



22 July 2015 – Switch to redundancy



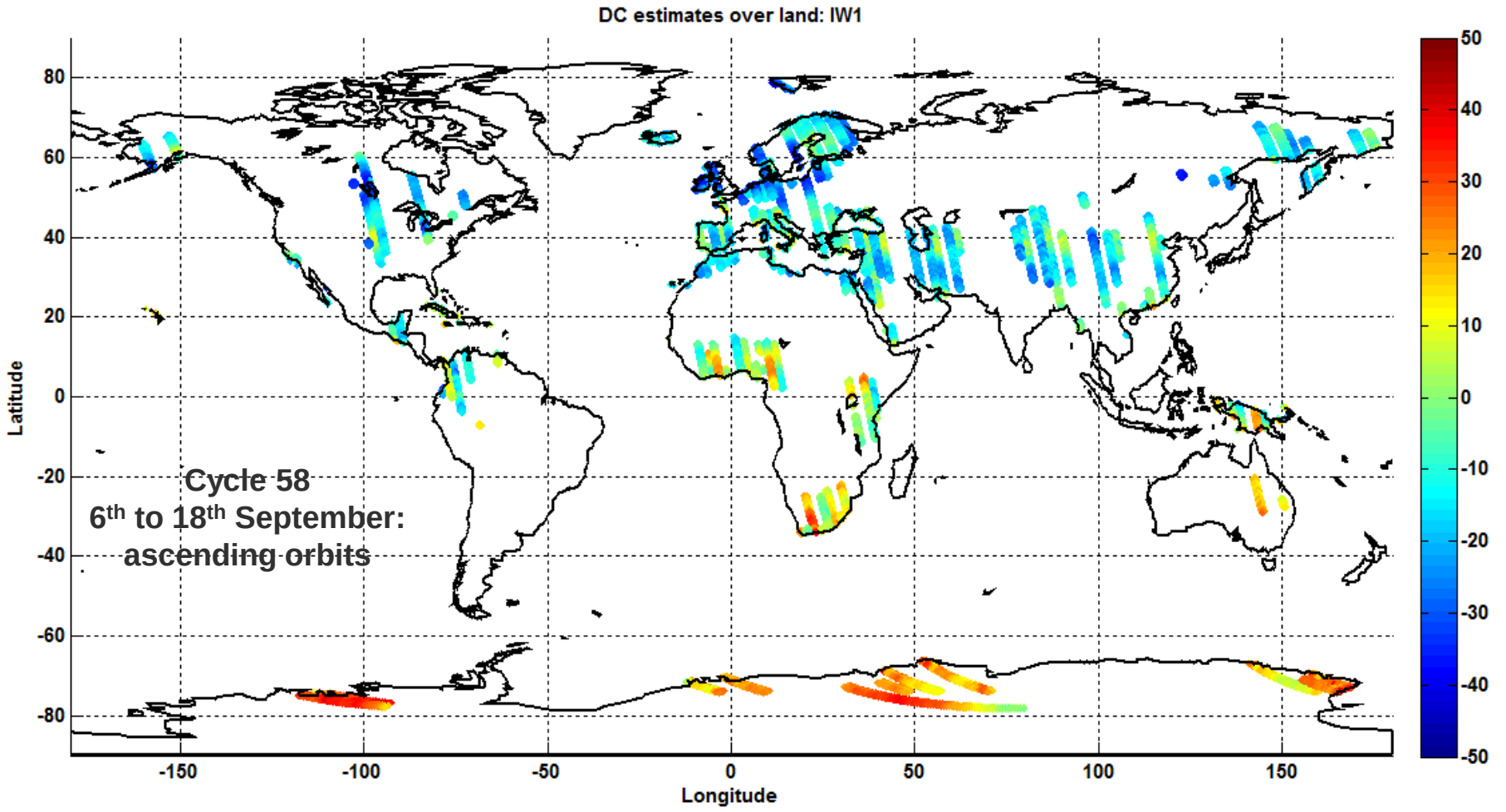


Antenna status - summary

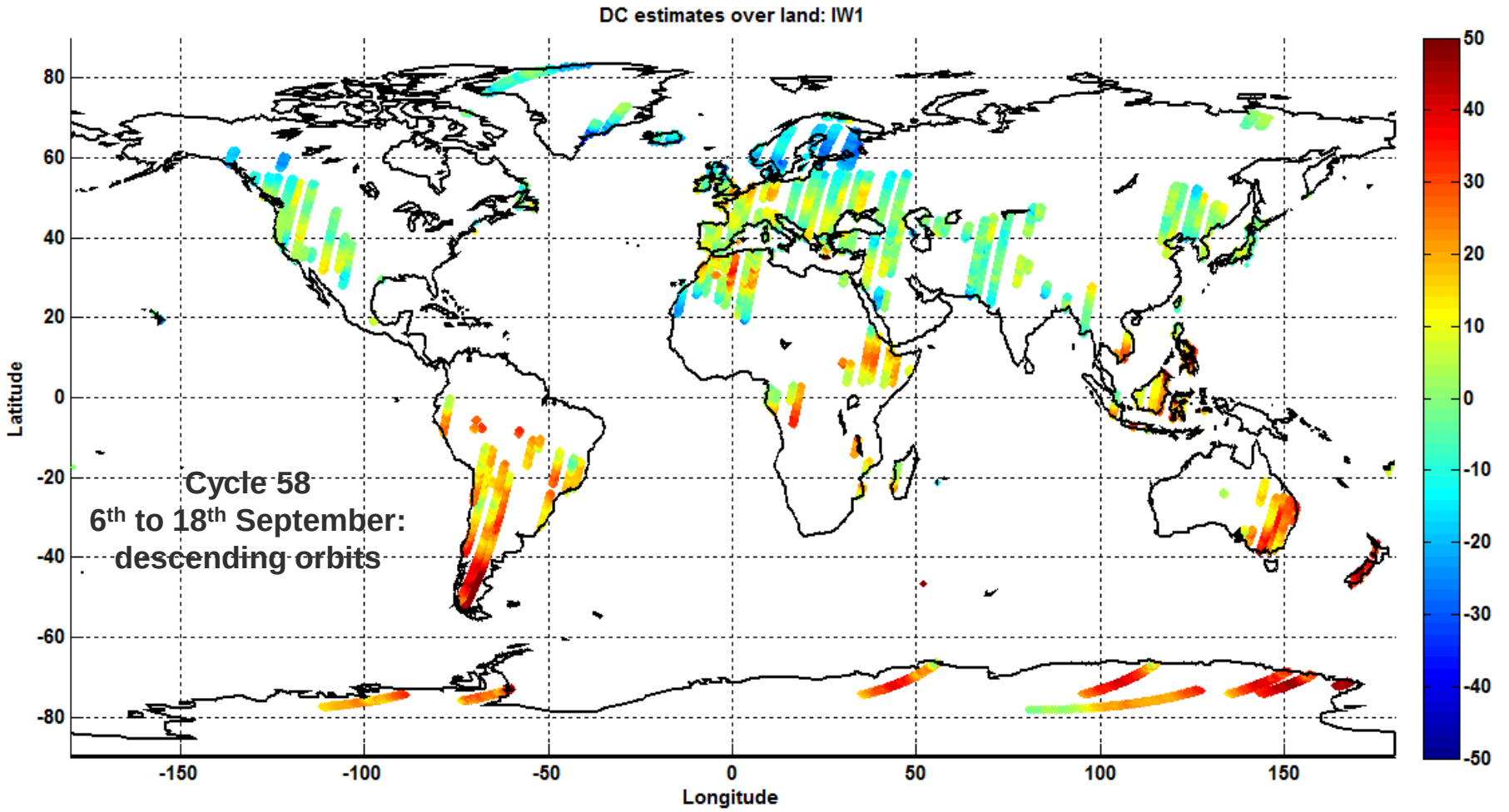
- The antenna status is daily monitored through the dedicated RFC mode
- 10 failures in total since launch:
  - 2 TX H-pol
  - 3 TX V-pol
  - 2 RX H-pol
  - 3 RX V-pol
- «Intermittent» failure of tile #5 in RX only, both polarizations, in the period Oct 2014 – July 2015
- Switch to redundancy on the 22 July 2015 resolved the issue.

Doppler Centroid

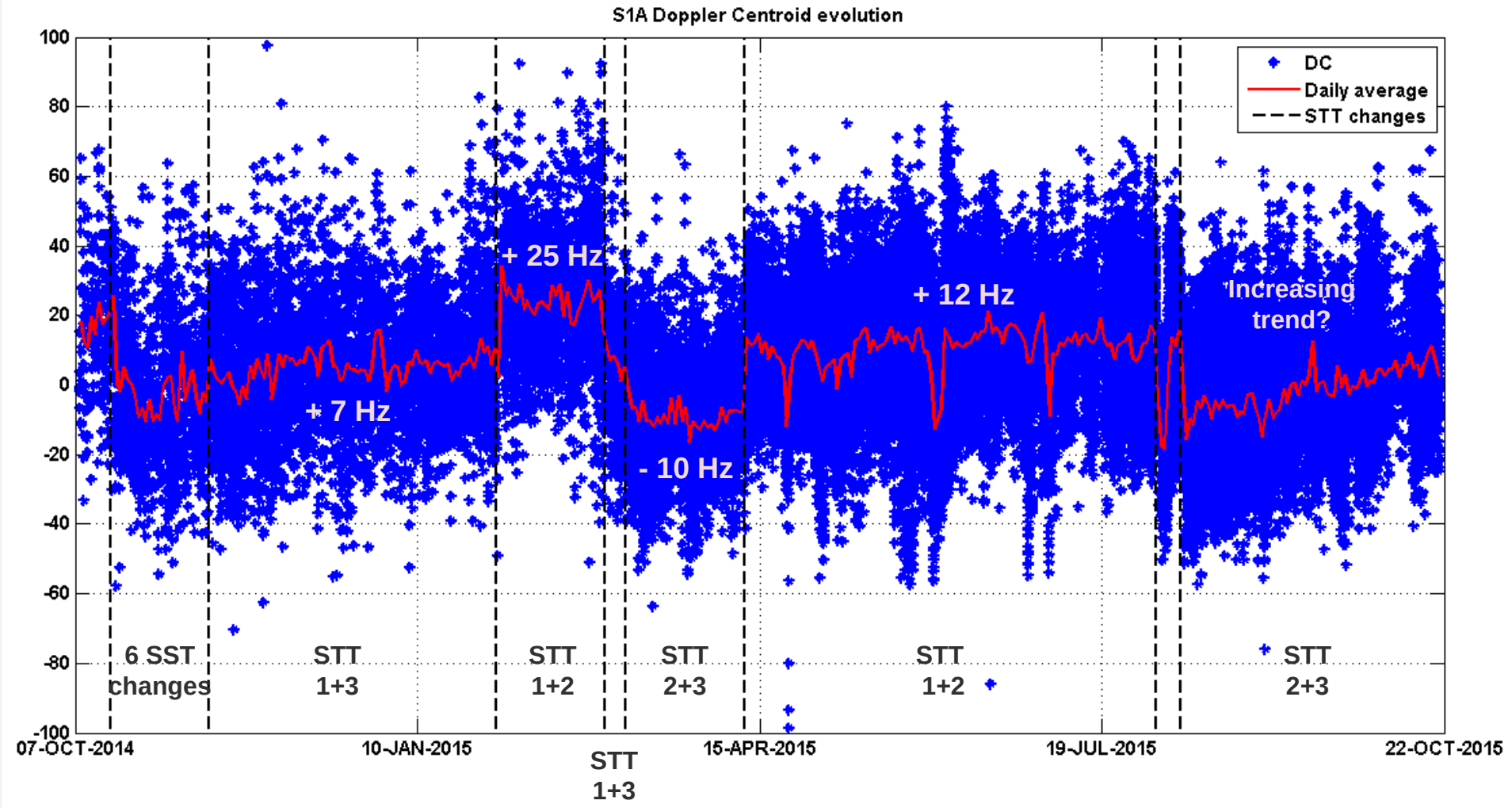
Doppler centroid evolution over 1 cycle



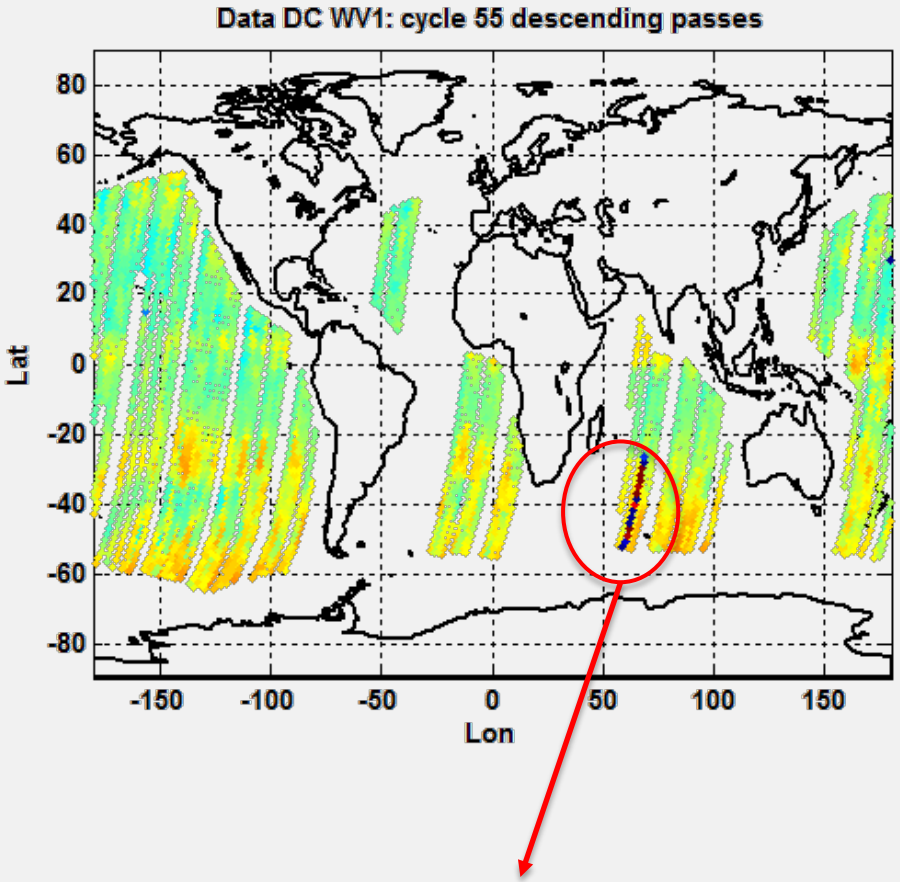
Doppler centroid evolution over 1 cycle

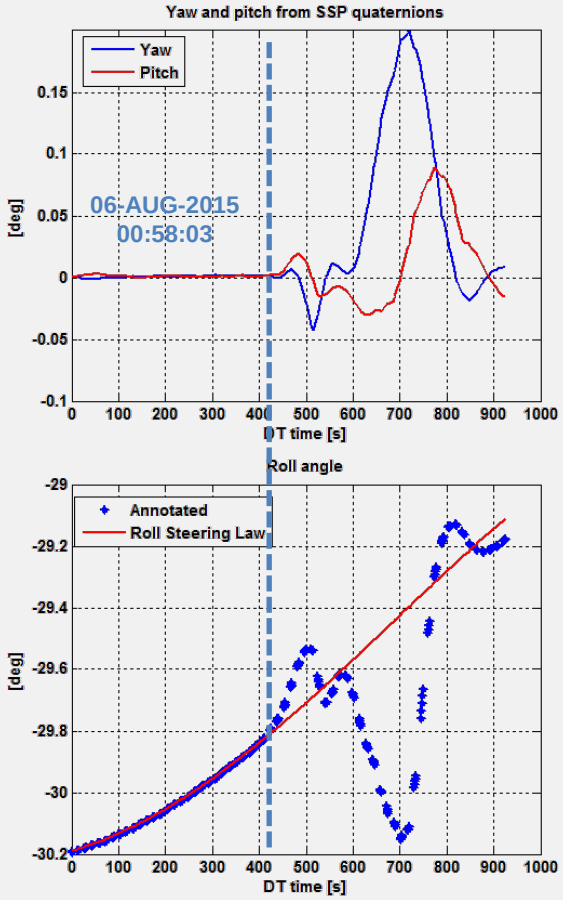


DC evolution during Zero Doppler period



Quaternions at work





- **acquisition with YSL disabled during S1A unavailability is “seen” by the quaternions**

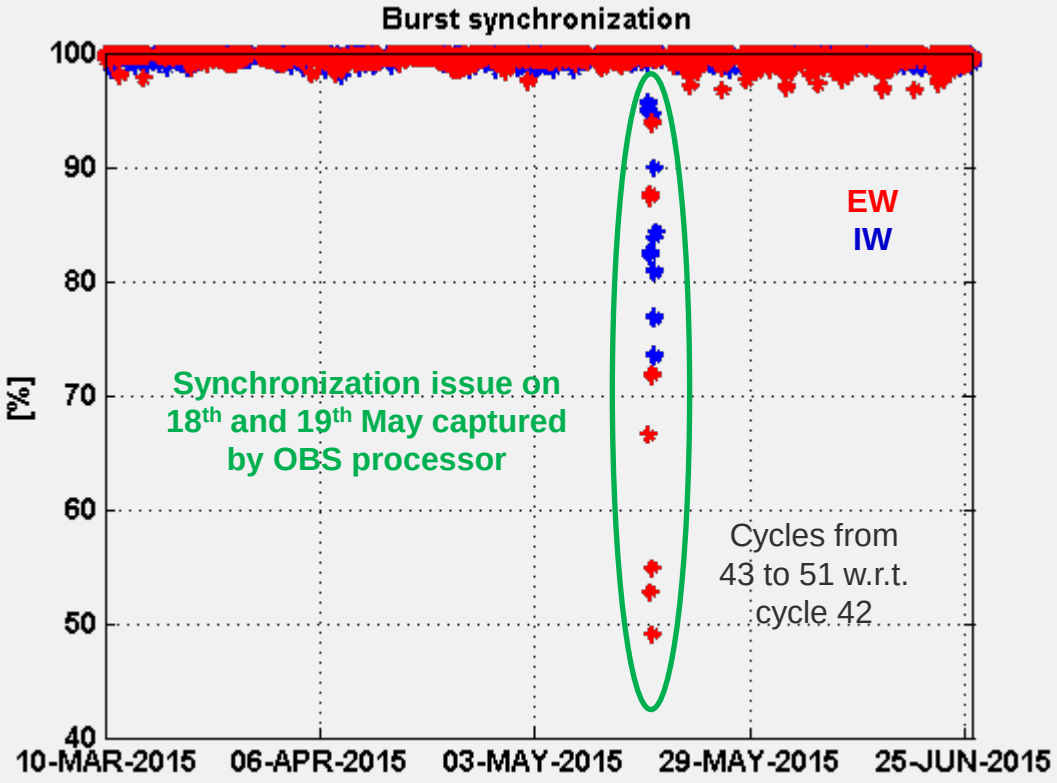
Doppler Centroid - summary

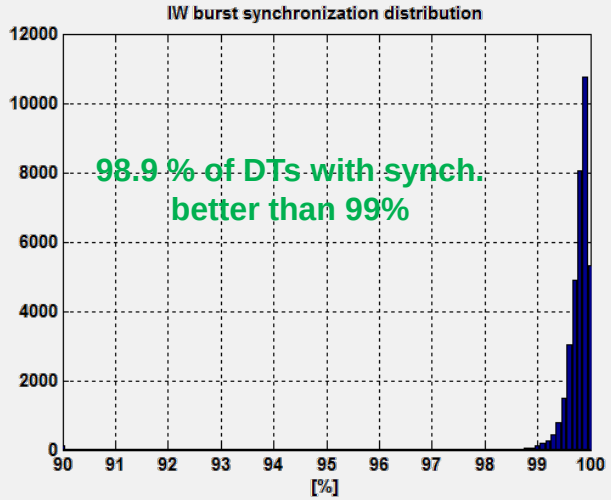
- The Doppler Centroid over land is limited within 50 Hz, confirming the effectiveness of the Zero-Doppler steering law.

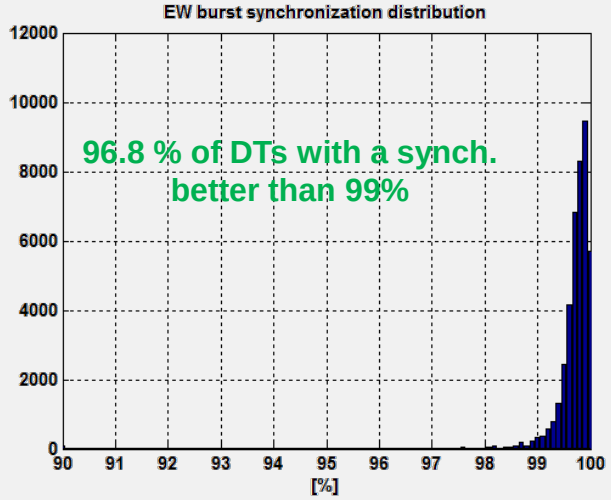
- The Star Trackers re-configuration events impact the overall bias of the Doppler Centroid and can be estimated from data. (No impacts on L1 data quality)

Burst Synchronization

Burst synchronization evolution



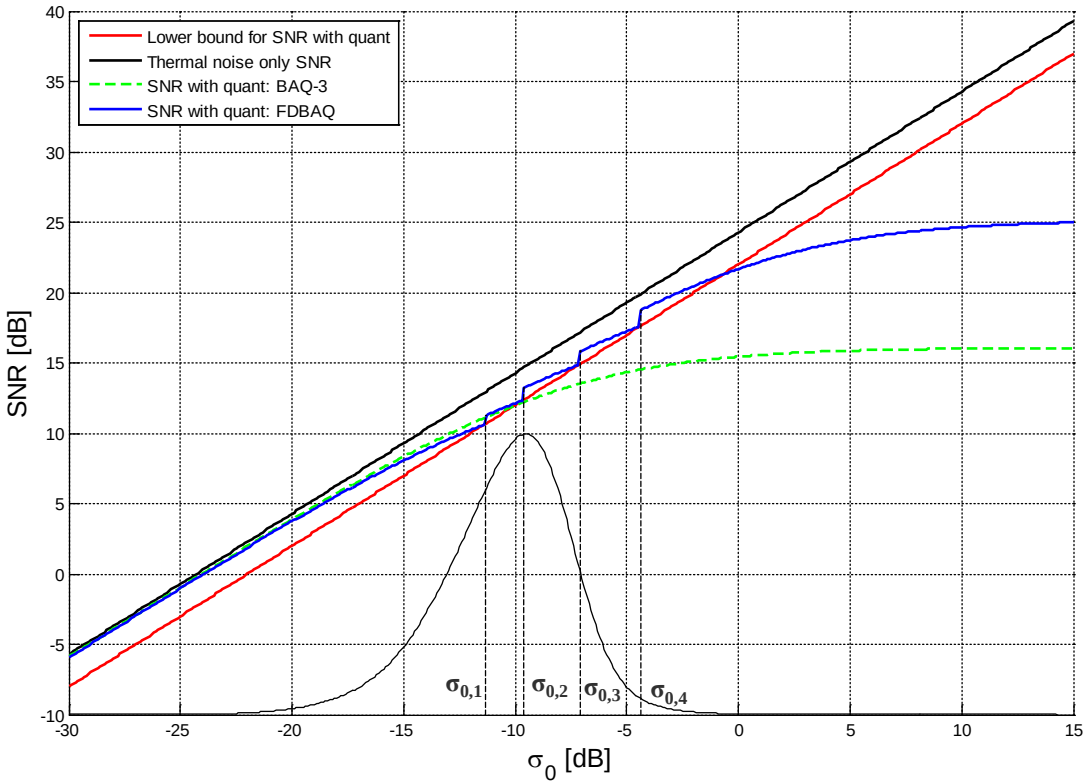




- **Burst synch within nominal values**

FDBAQ

Recall of the FDBAQ concept



Lower bound for SNR with quantization includ

$$SNR = \frac{\sigma_0}{\sigma_{0,\min}}, \qquad \sigma_{0,\min} = -22dB$$

Thermal noise only SNR

$$SNR = \frac{\eta_{foc}\sigma_0}{N_T}$$

SNR with BAQ-3 quantization included (SQNR

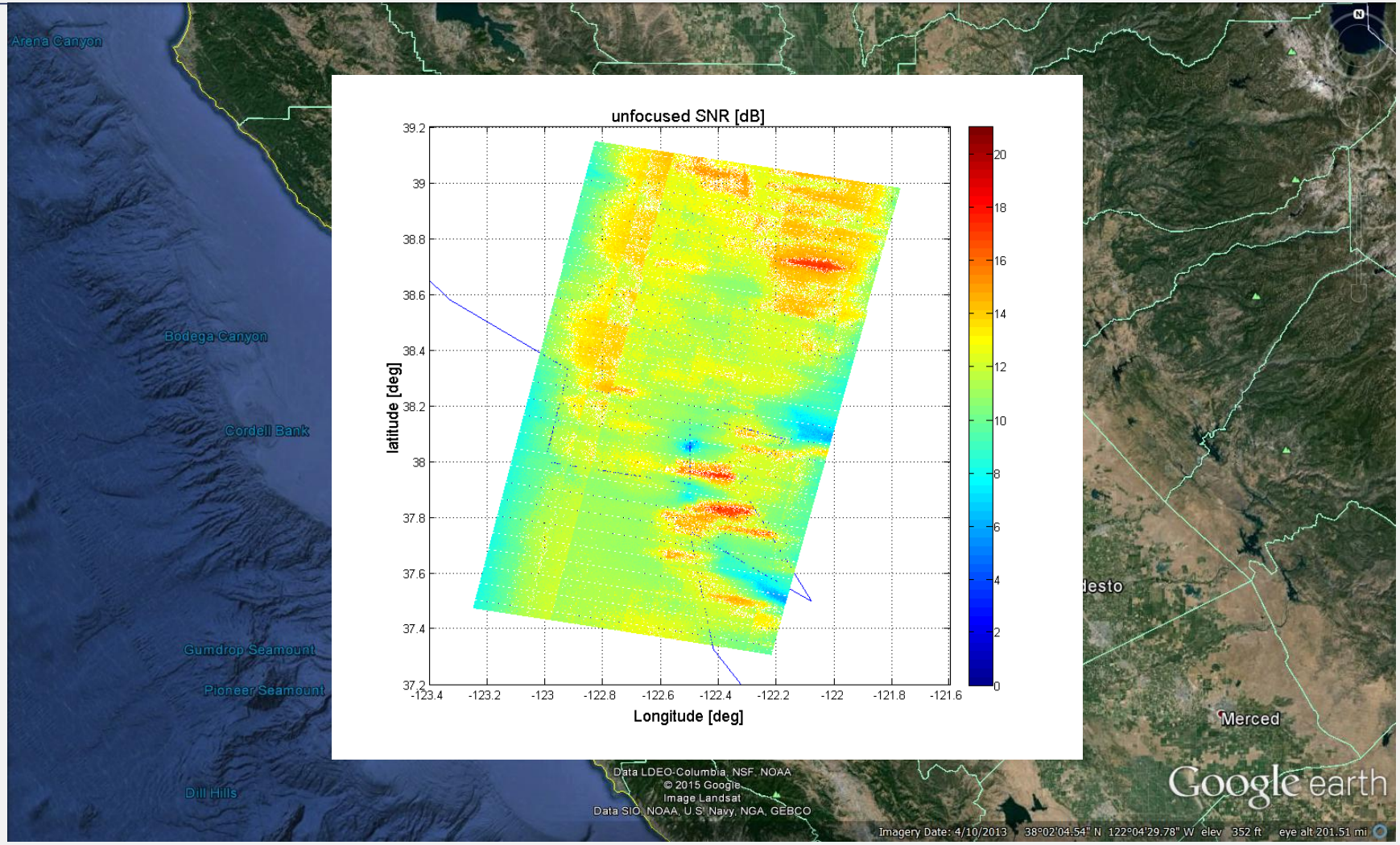
$$SNR = \frac{\sigma_0}{\frac{N_T}{\eta_{foc}} + \left(\frac{\sigma_0 / Q + N_T / \eta_{foc}}{SQNR_{BAQ3}} \right)}$$

SNR with FDBAQ quantization included

$$SNR = \frac{\sigma_0}{\frac{N_T}{\eta_{foc}} + \left(\frac{\sigma_0 / Q + N_T / \eta_{foc}}{SQNR_{FDBAQ_k}} \right)}$$

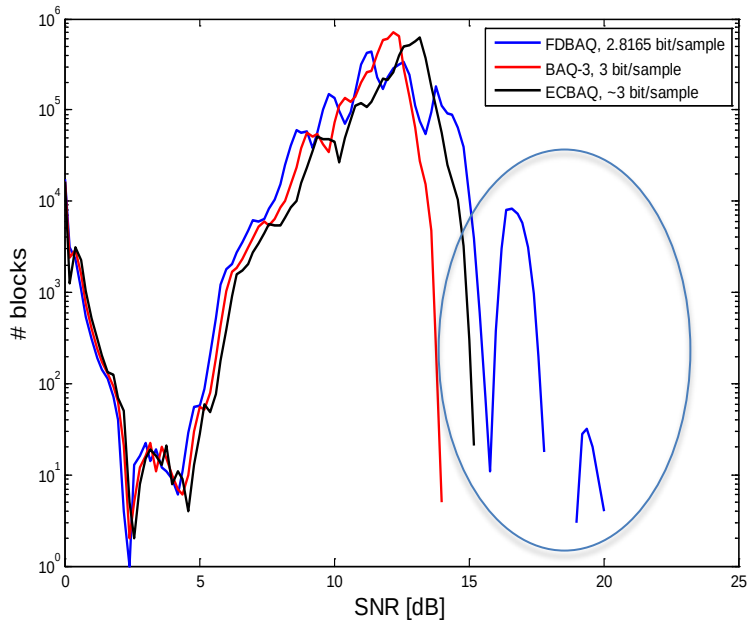
$$\hat{\sigma}_{0,k} = \left[\left(Q \cdot \sigma_{0,\min} - \frac{N_T}{\eta_{unfoc}} \right) \cdot SQNR_k - \frac{N_T}{\eta_{unfoc}} \right]$$

FDBAQ at work: example

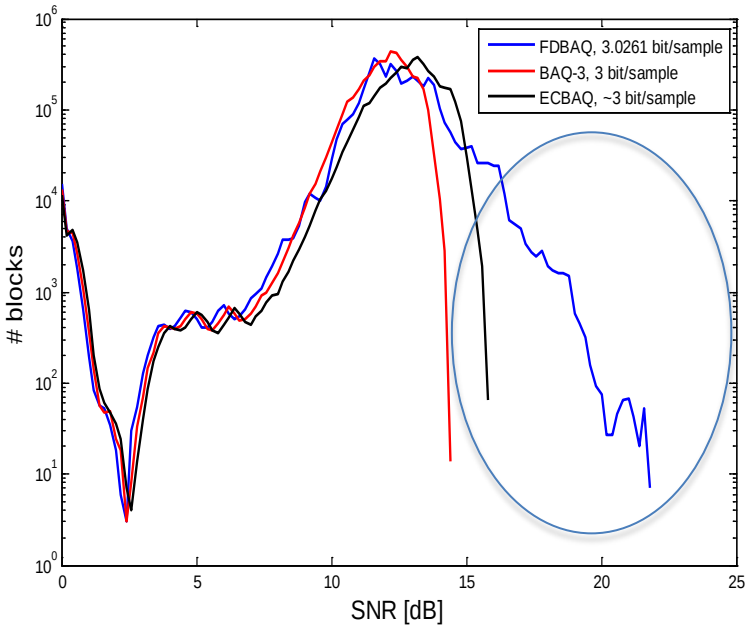


Data SNR statistics

Land scenario with cities



Forest scenario



FDBAQ - summary

- The FDBAQ quantization scheme performs correctly and provides an improved SNR for high-reflectivity targets

- The long-term statistics over the acquired data show that the average Mbit/s is :
  - [271.5 213.36 222.56 188.58 208.04 178.39] For Stripmap
  - 194.89 For IW
  - 62.32 For EW
  - [11.8 6.7] For WV
- The average bit/sample is <3.5, lower than BAQ4, with improved SNR

Thank you